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VACUUM SYSTEM PERFORMANCES ON SPIRAL FACILITY

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The SPIRAL facility has to produce radioactive ion beams from primary beams delivered by GANIL.
In order to avoid beam losses by charge exchange on the residual gas, the vacuum systems in the CIME cyclotron and the 60 meters long beam lines has been designed for reaching an ultimate vacuum pressure of about 5.10^{-6} Pa.
Global design and used technologies are described. The original conception of the CIME cryopumping system will be specially emphasized. Results and performances obtained are given.

1 Introduction

Radioactive ions produced from the GANIL heavy ions beams have to be transported through the twenty meters long TBE beam line before being accelerated in the new Cyclotron Ions Moyenne Energie (CIME) presently under beam testing [1] (fig 1). In order to minimize beam losses due to the charge exchange collisions between heaviest ions and residual gas, an average working pressure of about 5.10^{-6} Pa was required.

On beam lines, essential efforts was made on **reducing the gas flow** and conventional pumping systems used (commercial turbo and cryogenic vacuum pumps).

On Cime cyclotron, on the other hand, we had to work on **increasing the pumping speed** to expect reaching the low pressure required. Inside such a regular cyclotron, in a room temperature chamber with lots of elastomer o'rings and many different equipement, important outgassing amount is expected and estimated pumping speed of more than 25.000 l/sec was necessary.

In order to reach such a large pumping speed, a system of twin cryopanels installed inside the cyclotron (in the extraction valley) has been specially designed (fig.1).
The cryopanels cooling is supplied from cryogenerators located at some distance of the cryopanels. The cooling power is efficiently transfered by dual heat pipes operating with LN2 (for cooling the 80 K shielding) and LH2 (for cooling the 20 K cryopanel itself).
This cryopumping system, completed by two 2200 l/sec turbomolecular pumps, each connected on the two RF resonator tanks, is efficiently providing the requested pumping speed at the right location.

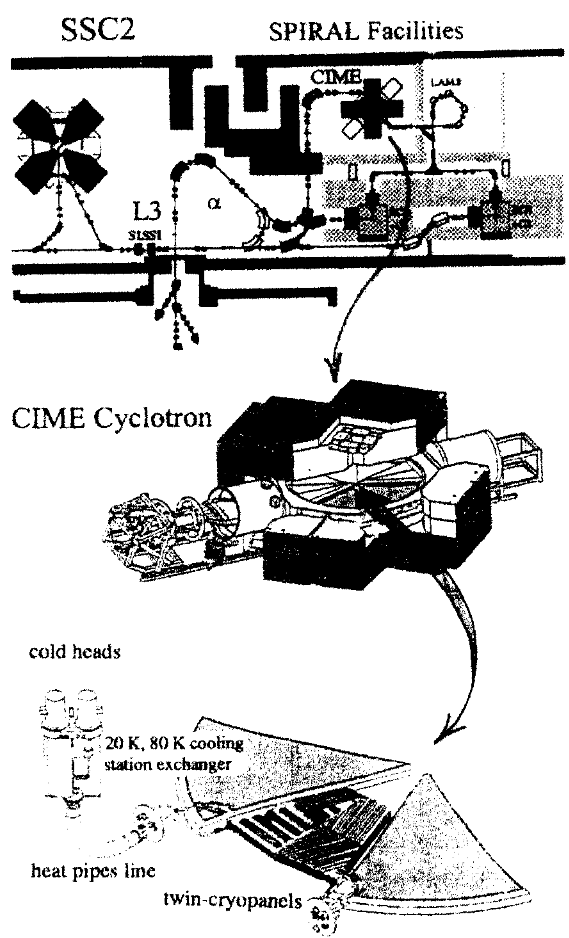

fig.1: Twin cryopanels on SPIRAL facilities

2 The vacuum system of the SPIRAL beam lines

Beam lines have three components:

- the high energy line, transporting the beam from the GANIL cyclotron (SSC 2) to the target (14 meters length).
- the very low energy beam line, transporting the secondary beam from the source to the centre of the CIME cyclotron (21 meters length).
- the medium energy beam line, transporting the secondary beam from the cyclotron to the experimental areas through the *alpha* spectrometer (24 meters length).

Calculations shows that beam line average pressures are imposed by:

- localised gas desorption of beam monitors
- pipe conductance in molecular flow regime
- distributed gas desorption of beam pipes

In order to obtain the required pressures, beam lines have been designed with metallic seals and low desorption rate marerials (chemically cleaning process). At the same time, improvements have been made for reducing beam monitor desorption flux. (fig.2)
The vacuum system is composed of localized cryogenic and turbomolecular pumps (0.5 to 1.5 $m^3.s^{-1}$ for N_2).

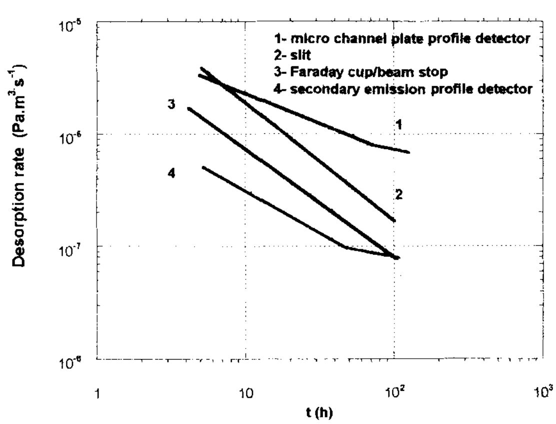

Figure 2 : Desorption rate of the different monitors used on SPIRAL beam-lines

During the first tests, the recorded pressures in the TBE (Très Basse Energie) beam line, between the ECR source and the CIME cyclotron, were 2.10^{-6} Pa to 9.10^{-6} Pa depending on the measurement points.

3 The CIME cryopumping system

In addition to the two 2200 l/sec turbomolecular vacuum pumps respectively connected on the two resonator tanks, **a system of twin cryopanels** located inside the cyclotron, to the bottom of a valley, between two poles, is providing large pumping speed to the accelerating region.

The twin cryopanel consists in an arrangement shown in fig.1 [2] : Each unit can be described as following:

-the 80 K screen (also used as efficient H2O pumping surface) is a flat copper box of a trapezoidal shape cooled with LN2 from the cooling module. On his upper side, a slatted baffle of about 0.34 m^2 can offer a large pumping conductance.

-it encloses a second box similar in shape which is LH2 cooled to some 20 K for N2, O2, CO, CO2 pumping. The internal gutter shaped parts, protected from the heat radiated, are covered with activated charcoal (about 350 grams on a total surface of 0.21 m^2) for hydrogen adsorption pumping.
Each cryopanel is cooling from a set of two cryogenerators by means of dual heat pipes for 80 K and 20K heat transfer. The heat station of each cryogenerator is equiped with a condenser block made of copper, connected in pairs to a commun heat pipe line for supplying the liquid or returning the vapour. The bundle of these four super-insulated flexible heat pipe lines terminates in a fourfold bayonet coupling.

The basic principle of such a system has already been experienced for the vacuum system on AGOR (KVI lab at Groningen) [3].
Using the phase changing properties Liquid/Vapour of N2 and H2 respectively, this principle allows efficient heat transfer, over several meters, with very small temperature gradient.
For having liquid and vapour coexisting in the heat pipe, pressure and temperature conditions must keep the fluid state within its triple point and its critical point; the chosen fluid must therefore have its properties in agreement with the temperature we want to transfer the refrigeration power, so:

- we are using liquid/gaseous NITROGEN for each loop assigned to the 80 K shielding and liquid/gaseous HYDROGEN for the 20 K cryopanel loops.

The masses of gases respectively involved for heating transfer are:

- about 30 grams in each N2 heat pipe loop
- a little more than 6 grams in each H2 heat pipe loop. Such a minimum mass of hydrogen involved in the process is appreciated for security reasons.

When the system is running, condensed gases drop from the cold head condensors and go down for cooling cryopanels, then, vapour return up to the cold head for being condensed again.

Both cooling system (each other including two cold head merging inside their common tank and the flexible heat pipe line) are **identical.**

Each flexible heat pipe line is ended by a fourfold bayonet coupling and **can be connected on any** cryopanel **feedthrough.**

Cryopanels are each others **symetrical** and **can run separately.**
Running beetwen 10^{-5} and 10^{-6} Pa, the normal autonomy of such a system should be at least a few months. But, an integrated heating system can provide, at will, enough power for warming up cryopanel from 20 K to 80 K or 300 K in less than two hours.

4 Vacuum performances

Graphes on fig.3 and 3bis show the first cryopanel cooling and pumping down on december 1997, inside the CIME cyclotron chamber.

The cooldown time (depending on the cooling power available and the masses involved) is about 10 hours.
For each cooling module, where two cold heads merging in a common vacuum tank are feeding from a single compressor unit, the refrigeration power available is:

- 72 watt (2 x 36 watt) for the LN2/N2 heat pipe
- 19 watt (2 x 9.5 watt) for the LH2/N2 heat pipe

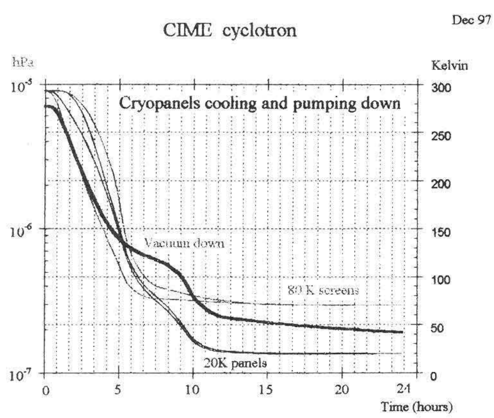

fig.3 first pumping down (dec.97)

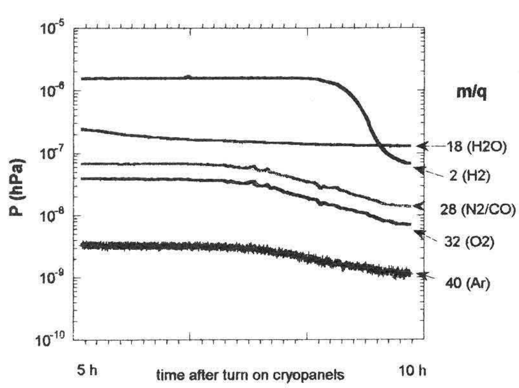

fig.3bis residual gases while pumping down

For each cryopanel unit, the masses to cool are:

- 12 kg from 300 K to 80 K
- 6.5 kg from 300 K to 20 K

In order to reduce substancially the radiated heat load from the warm surrounding, a highly reflective radiation shield has been hanged on the top, above cryopanels.

However, we noticed that pumping effects begin at substancially high temperature,very soon after starting the cryopanel cooling.

Beetwen the 8th and 10th hours, we can observe spectacular H2 pumping whose partial pressure (fig. 3bis) drops below partial H2O pressure level. The H2 pumping efficiency on activated coal can be obviously observed from 50 K.

Fig.4 shows the more recent cryopumping down, on april 1998. After 24 hours, a vacuum pressure of 4.10^{-6} Pa has been reached.
Due to the special size and shape of these twin cryopanels, normalized **pumping speed** measurements could not be done. But theoretical calculations corroborated the vacuum results for leading to the following estimations:

- **2 x 60 000 l/sec** for **H2O vapour**
- **2 x 15 000 l/sec** for **air** or **nitrogen**
- **2 x 22 000 l/sec** for **hydrogen**

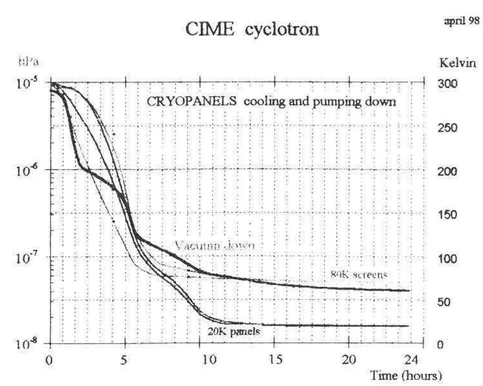

fig.4 last pumping down (april 98)

5 Conclusions

By using the phase changing fluid properties, heat pipes principle allows **important heat tansfert on several meters** and **under** almost **constant temperature**.
Cryopanels system suitably adapted inside a vacuum chamber and just feeding from a cryogenic line, allow a best efficiency
The CIME cyclotron twin cryopanel is a good and original exemple of a device providing large pumping speed *in situ*, with remarquable performances.

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